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**Water reuse in urban areas —  
Guidelines for water reuse safety  
evaluation — Stability evaluation of  
reclaimed water**

*Recyclage des eaux dans les zones urbaines — Lignes directrices  
concernant l'évaluation de la sécurité du recyclage de l'eau —  
Évaluation de la stabilité de l'eau réutilisée*

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Published in Switzerland

# Contents

Page

|                                                                                                                              |           |
|------------------------------------------------------------------------------------------------------------------------------|-----------|
| <b>Foreword</b>                                                                                                              | <b>iv</b> |
| <b>Introduction</b>                                                                                                          | <b>v</b>  |
| <b>1 Scope</b>                                                                                                               | <b>1</b>  |
| <b>2 Normative references</b>                                                                                                | <b>1</b>  |
| <b>3 Terms and definitions</b>                                                                                               | <b>1</b>  |
| <b>4 Abbreviated terms</b>                                                                                                   | <b>2</b>  |
| <b>5 Water quality stability</b>                                                                                             | <b>3</b>  |
| 5.1 General                                                                                                                  | 3         |
| 5.2 Evaluation principles of water quality stability                                                                         | 6         |
| <b>6 Evaluation system of water quality stability</b>                                                                        | <b>7</b>  |
| <b>7 Evaluation parameters of water quality stability</b>                                                                    | <b>8</b>  |
| 7.1 General                                                                                                                  | 8         |
| 7.2 Single parameters                                                                                                        | 8         |
| 7.3 Composite parameters                                                                                                     | 11        |
| 7.3.1 General                                                                                                                | 11        |
| 7.3.2 Langelier saturation index (LSI)                                                                                       | 12        |
| 7.3.3 Ryznar stability index (RSI)                                                                                           | 12        |
| 7.3.4 Calcium carbonate precipitation potential (CCPP)                                                                       | 13        |
| 7.3.5 Aggressive index (AI)                                                                                                  | 13        |
| 7.3.6 Larson corrosion index (LR)                                                                                            | 13        |
| 7.3.7 Riddick corrosion index (RI)                                                                                           | 14        |
| 7.4 Selection principles of evaluation parameters                                                                            | 15        |
| 7.5 Case study of evaluation parameters selection                                                                            | 16        |
| <b>8 Evaluation parameters of water quality stability for pipeline networks</b>                                              | <b>17</b> |
| <b>9 Evaluation parameters of water quality stability for equipment</b>                                                      | <b>17</b> |
| <b>Annex A (informative) Information on corrosion types</b>                                                                  | <b>19</b> |
| <b>Annex B (informative) Chemical stability guidelines for water quality in urban water supply systems of some countries</b> | <b>20</b> |
| <b>Annex C (informative) Guidelines for water conditioning of boiler water in Japan</b>                                      | <b>21</b> |
| <b>Annex D (informative) Reuse of urban recycling water — Water quality standard for industrial use in China</b>             | <b>22</b> |
| <b>Annex E (informative) Water quality parameter limits of reclaimed water depending on specific use</b>                     | <b>24</b> |
| <b>Annex F (informative) Modification methods based on the original AOC method</b>                                           | <b>25</b> |
| <b>Annex G (informative) Biological stability guideline values for AOC</b>                                                   | <b>26</b> |
| <b>Annex H (informative) Comparison of measurement methods for evaluation parameters of biological stability</b>             | <b>27</b> |
| <b>Annex I (informative) Chemical stability evaluation conclusions for different composite parameters</b>                    | <b>28</b> |
| <b>Annex J (informative) Guideline values of reclaimed water used in toilet flushing</b>                                     | <b>29</b> |
| <b>Annex K (informative) Guideline values of reclaimed water used for recreational purposes</b>                              | <b>30</b> |
| <b>Bibliography</b>                                                                                                          | <b>31</b> |

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 282, *Water reuse*, Subcommittee SC 2, *Water reuse in urban areas*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

With economic development and population growth, the demand for water resources is steadily increasing. Combined with the exploitation and utilization of water, numerous countries and regions have faced water shortages to different degrees. Increasing efforts have been made to solve the water crisis.

Water reuse has been recognized as a low-cost and effective means to alleviate water resource shortages. Wastewater usually contains a variety of pathogens, chemical pollutants and nutrients. Traditional water treatment cannot remove all pollutants. During the long-term utilization of reclaimed water, residual pollutants will affect human health (e.g. potential health risks to the public and workers handling the reclaimed water), ecological environment (e.g. pollution of receiving water, soil) and production safety (e.g. harmful effects on equipment operation such as corrosion, scaling and fouling). Therefore, water quality stability is a prerequisite to ensure water reuse. It is necessary to monitor and manage the quality of reclaimed water to ensure a safe supply. Chemical stability and biological stability are crucial aspects of water quality stability. Water quality instability usually leads to frequent occurrences of corrosion, scaling and fouling, bacterial regrowth, increasing energy consumption and reduced service life of relevant equipment.

There are limited guidelines or regulations specifically regarding water quality stability for urban purposes of reclaimed water at a global level. For different types of reclaimed water applications, the selection of stability evaluation parameters remains controversial. Stability evaluation and management of water quality are important to ensure safe utilization of reclaimed water. It is necessary to establish a standard for comprehensively evaluating the stability of reclaimed water.

This document aims to provide guidance on water quality stability of reclaimed water and provide stability parameters and methods based on different needs and utilization of reclaimed water. This document includes:

- standard terms and definitions;
- evaluation principles of water quality stability for reclaimed water;
- evaluation parameters of water quality stability for reclaimed water;
- the selection of stability evaluation parameters for pipeline networks and equipment related to reclaimed water;
- evaluation methods of water quality stability for reclaimed water.

Critical values of evaluation parameters for water quality stability are out of the scope of this document. The ranges of different evaluation parameters are provided for reference. The water stability control or management involving the reclamation treatment and/or the distribution system management (e.g. residual disinfectant) are also out of the scope of this document.

This document provides guidance on storage, transportation and application of reclaimed water. The beneficial aspects are reduction of energy consumption, expansion of service life of equipment and reduction of operation costs.

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# Water reuse in urban areas — Guidelines for water reuse safety evaluation — Stability evaluation of reclaimed water

## 1 Scope

This document provides parameters and methods for water quality stability evaluation of reclaimed water. This document can be used in various stages of water reclamation projects including storage, transportation, application and post-assessment.

This document considers the needs and utilization of reclaimed water and is applicable to the evaluation and management of water quality stability of reclaimed water from municipal wastewater sources, including chemical stability and biological stability.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 20670, *Water reuse — Vocabulary*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20670 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

### 3.1

#### **assimilable organic carbon**

#### **AOC**

organic carbon which can be used by microorganisms for assimilation

[SOURCE: ISO 23070:2020, 3.1]

### 3.2

#### **corrosion**

physicochemical interaction between a metallic material and its environment that results in changes in the properties of the metal and that can lead to significant impairment of the function of the metal, the environment or the technical system, of which these form a part

[SOURCE: ISO 8044:2020, 3.1, modified — Note 1 to entry removed.]

### 3.3

#### **critical value**

boundaries of acceptable values for evaluation parameters when water quality is stable

### 3.4

#### **fouling**

precipitation of suspended solids, including living organisms (biofouling) and chemical substances (inorganic or organic)

**3.5**  
**microbiologically influenced corrosion**  
**MIC**

*corrosion* (3.2) influenced by the action of microorganisms

[SOURCE: ISO 8044:2020, 4.37, modified — Note 1 to entry removed.]

**3.6**  
**scaling**  
crystalline scales caused by the oversaturation of chemical substances on metallic or non-metallic surfaces

**4 Abbreviated terms**

|                   |                                            |
|-------------------|--------------------------------------------|
| AI                | aggressive index                           |
| AOC               | assimilable organic carbon                 |
| ATP               | adenosine triphosphate                     |
| BDOC              | biodegradable dissolved organic carbon     |
| BFR               | biofilm formation rate                     |
| BGP               | bacterial growth potential                 |
| CCPP              | calcium carbonate precipitation potential  |
| COD <sub>Cr</sub> | chemical oxygen demand (dichromate method) |
| DO                | dissolved oxygen                           |
| DBP               | disinfection by-product                    |
| ILR               | improved Larson corrosion index            |
| LR                | Larson corrosion index                     |
| LSI               | Langelier saturation index                 |
| MAP               | microbially available phosphorus           |
| MIC               | microbiologically influenced corrosion     |
| MPN               | most probable number                       |
| RI                | Riddick corrosion index                    |
| RSI               | Ryznar stability index                     |
| TDS               | total dissolved solids                     |
| TN                | total nitrogen                             |
| TP                | total phosphorus                           |
| TSS               | total suspended solids                     |

## 5 Water quality stability

### 5.1 General

Water quality stability is the premise of reclaimed water use. The recommended parameters for water reuse safety in ISO 20761 include routine physical and chemical parameters, aesthetic parameters, microbial parameters, stability parameters and toxic and harmful chemicals.<sup>[1]</sup> Among stability parameters, chemical stability and biological stability are important aspects.

Chemical stability includes corrosion, scaling and fouling. Corrosion can be classified into many types, such as electrochemical corrosion, chemical corrosion, localized corrosion, pitting corrosion and layer corrosion. Detailed information is given in [Annex A. Table 1](#) lists factors influencing the likelihood of corrosion. The main influencing factors include characteristics of equipment and pipelines, characteristics of the reclaimed water and operating conditions. Reclaimed water can be used in many fields for urban areas, such as industrial use, artificial landscape amenity, municipal non-potable use and groundwater recharge. Related equipment includes boilers and heat exchangers, irrigation equipment, air conditioning and toilet flushing devices. Related pipelines include steel and galvanized steel pipelines, concrete and cement pipelines, cement-mortar-lined metal pipelines, plastic pipelines, cast-iron and ductile-cast-iron pipelines and non-ferrous metal pipelines. Operating conditions include temperature, flow conditions and pressure conditions. Scaling is mainly dependent on two situations. One is the decrease in the solubility of ionic components, which lead to crystals precipitation when thermodynamic conditions change. The other is precipitation formed by reactions between different ionic components. Fouling is mainly caused by the precipitation of suspended chemicals. The extent of fouling is affected by hydraulic conditions, the roughness of the contact surfaces and the concentration, size and type of suspended chemicals.

**Table 1 — Factors influencing the likelihood of corrosion**

| Characteristics of equipment and pipelines | Characteristics of the water       | Operating conditions                                                                                     |
|--------------------------------------------|------------------------------------|----------------------------------------------------------------------------------------------------------|
| — Chemical composition                     | — Physico-chemical composition     | — Temperature                                                                                            |
| — Surface conditions                       | — Colloidal and particulate matter | — Flow conditions, such as flow velocity, turbulence or laminar flow, continuous or intermittent pattern |
| — Design and construction                  | — Living organisms                 | — Pressure conditions                                                                                    |

Besides chemical stability, considering the possibility of opportunistic bacterial regrowth in reclaimed water, biological stability is also an important aspect of water quality stability. Biological stability includes MIC and biofouling. MIC is due to microbial activity involving bacteria, archaea and fungi. Within bacteria, sulfate-reducing bacteria, sulfur-oxidising bacteria, iron-oxidising or reducing bacteria, acid-producing bacteria and bacteria that excrete extra-cellular polymeric substances significantly affect corrosion. Among these, some microbes can coexist and their cooperative metabolisms can lead to increasing corrosion rates. Microbes can directly cause MIC by producing acids and they can accelerate the corrosion of pre-existing agents such as  $O_2$  and  $CO_2$  by damaging mineral passivation films on metal surfaces. Moreover, the major mechanisms of MIC include fixing anodic sites, formation of differential aeration or chemical concentration cells and cathodic depolarisation. MIC can cause corrosion to various materials such as carbon steel, stainless steel, aluminium alloy, magnesium, zinc and concrete.<sup>[2]</sup> Biofouling is caused by the excessive growth of biofilm. Biofilm is the aggregate of microbial cells formed by microorganisms developing layers of polymer-like materials, called extra-cellular polymeric substances, and attached at a surface-liquid interface. Microbial adhesion to surfaces is governed by surface-charge, -free energy and -roughness. Electrostatic, hydrophobic and chemical forces can cause microbial attachment to surfaces. Due to extra-cellular enzymes in the biofilm, microorganisms can utilize complex organic substrates, such as humic acids that are not easily biodegradable by microorganisms in bulk water, which enables the growth of different microorganisms present in bulk water. Biofilm can also protect microorganisms from disinfectants and toxins in the surrounding environment. The formation of biofilm is dependent on various environmental conditions,

such as salinity, temperature, conductivity, pH, DO level, BDOC and AOC content and hydrodynamic conditions. In addition, it is not recommended that caustics are used to reduce biofilm formation in pipeline networks, because some bacteria from biofilm can survive under unfavourable conditions (higher pH values).

Water quality stability is affected by many factors, including physical, chemical and biological factors. Examples of related influencing factors on water quality stability are shown in [Table 2](#) and [Table 3](#).

**Table 2 — Examples of related influencing factors on chemical stability**

| Influencing factors        | Notes of significance                                                                                                                                                                                                                                                                          |
|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Calcium and magnesium ions | Calcium and magnesium ions determine water hardness.<br>Low hardness is beneficial for passivation film formation on the inner wall of pipeline networks, which can prevent further corrosion.<br>High hardness can lead to scale formation.                                                   |
| Chloride                   | High concentration of chloride can increase conductivity of water, accelerate migration rate of ions and electrons in the water and accelerate corrosion. More specifically, high concentration of chloride can cause pitting corrosion, especially for stainless steel.                       |
| Sulfate                    | High concentration of sulfate can increase conductivity of water, accelerate migration rate of ions and electrons in the water and accelerate corrosion.<br>Sulfate can easily cause scale formation when calcium ions exist.                                                                  |
| Nitrate                    | Nitrate can greatly accelerate the general corrosion of iron in acidic solutions but has slight influence on the general corrosion in neutral solutions. <sup>[3]</sup>                                                                                                                        |
| DO                         | When DO acts on the inner wall of pipeline networks, it can accelerate corrosion.<br>When DO acts on the surface of formed corrosion products, it can promote passivation films formation and prevent further corrosion.                                                                       |
| Carbon dioxide             | High contents of carbon dioxide can decrease pH value and corrode metals.                                                                                                                                                                                                                      |
| Silicon dioxide            | Excessive silicon dioxide can form hard scales, especially for heat exchangers.                                                                                                                                                                                                                |
| Iron                       | Iron can form red iron hydroxide precipitation, causing scale formation.<br>Water containing iron bicarbonate can also cause corrosion.                                                                                                                                                        |
| pH                         | The increase of pH within specific limits (pH 7,5 to pH 9,5) can reduce the release of iron. Higher pH can increase the oxidation rate of Fe(II) and formed Fe(III) can intensify the physical structure of tubercles, thus inhibiting the release of internal iron.                           |
| TSS                        | TSS are easily disturbed by water flow and can acceleratively scour off corrosion surface layer, thus aggravating erosion of water flow on the inner wall of pipelines.<br>Suspended solids are nuclei of salt crystals. Excessive suspended solids will also promote the formation of scales. |

Table 3 — Examples of related influencing factors on biological stability

| Influencing factors |            | Notes of significance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|---------------------|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| AOC                 |            | AOC can provide carbon and energy for heterotrophic bacteria and is generally considered a major limiting factor for the growth of heterotrophic bacteria.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| BDOC                |            | BDOC is considered as the hydrolysable pool of carbon available for bacterial growth and biofilm formation in the distribution system. The BDOC can be used to evaluate the reduction in chlorine demand or disinfection by-product (DBP) formation potential through a biological process.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Inorganic nutrients | Nitrogen   | <p>Due to bacterial elemental composition (e.g. molar ratio C:N:P is 100:20:1,7), nitrogen is also required for heterotrophic growth, though in considerably smaller amounts than organic carbon. The lack of nitrogen will limit the growth of heterotrophic bacteria.</p> <p>Ammonia can be oxidized to nitrous acid by ammonia-oxidizing bacteria, which simultaneously leads to pH decrease. Under low pH value, pipelines of carbon steel, copper, aluminium and other metals are prone to corrode.</p> <p>Nitrate-reducing bacteria can utilize nitrate and generate nitrogen gas which is not corrosive, which prevents corrosion through competition with sulfate reduction by sulfate-reducing bacteria.</p>                                                                                                                                  |
|                     | Phosphorus | Phosphorus is an important limiting factor for bacterial growth, among which phosphate can provide nutrient source for bacteria. Compared with carbon content, phosphorus content required by bacteria is lower. The content of phosphorus in the effluent water depends on the removal efficiency of the treatment process.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|                     | Sulfur     | <p>Sulfur-oxidizing bacteria can oxidize elemental sulfur and sulfide, and produce sulfate and corrosive sulfuric acid, which can increase acidity, hydrogen penetration and corrosion rates. The presence of sulfur-oxidizing bacteria can promote the growth of sulfate-reducing bacteria by producing the products necessary for their growth (e.g. sulfate).<sup>[4]</sup></p> <p>Sulfate-reducing bacteria can use the oxygen component of sulfate for respiration and generate hydrogen sulfide in the absence of DO or in biofilm. The sulfide will come out of solution at various pH ranges and then convert to sulfuric acid by sulfur-oxidizing bacteria, which will easily lead to corrosion in concrete sewers. Just like sulfate-reducing bacteria, thermophilic sulfate-reducing archaea can also cause corrosion in a similar way.</p> |
|                     | Iron       | <p>Iron-oxidizing bacteria can oxidize divalent iron Fe(II) to trivalent ion Fe(III) by using DO and produce large amounts of iron oxide precipitates, which can alter the acidity and promote corrosion. In biofilm, aerobic or facultative iron-oxidizing bacteria can provide an oxygen-free local environment for sulfate-reducing bacteria growth, which can lead to more severe corrosion.<sup>[4]</sup></p> <p>Iron-reducing bacteria can promote corrosion by altering minerals adhering to alloyed steel, removing passivating layers and increasing the concentration of Fe(II) and ferrous sulfide formed by mixed communities.<sup>[4]</sup></p>                                                                                                                                                                                           |
| DO                  |            | <p>The absence of DO can provide suitable conditions for anaerobic bacteria growth, such as sulfate-reducing bacteria and iron-reducing bacteria.</p> <p>Low DO levels can provide suitable conditions for facultative bacteria growth, such as nitrate-reducing bacteria and sulfate-reducing bacteria.</p> <p>High DO levels can provide suitable conditions for aerobic bacteria growth, such as ammonia-oxidizing bacteria, sulfur-oxidizing bacteria and iron-oxidizing bacteria.</p> <p>High pressure and low temperature can increase DO solubility in water and prevent anaerobic conditions in pipelines; high temperature can decrease DO levels.</p> <p>The metabolism of microorganisms in biofilm can lead to concentration gradients of DO and affect microbial community compositions.</p>                                              |

**Table 3** (continued)

| Influencing factors  |                      | Notes of significance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------------------|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| AOC                  |                      | AOC can provide carbon and energy for heterotrophic bacteria and is generally considered a major limiting factor for the growth of heterotrophic bacteria.                                                                                                                                                                                                                                                                                                                                                                                       |
| BDOC                 |                      | BDOC is considered as the hydrolysable pool of carbon available for bacterial growth and biofilm formation in the distribution system. The BDOC can be used to evaluate the reduction in chlorine demand or disinfection by-product (DBP) formation potential through a biological process.                                                                                                                                                                                                                                                      |
| Operating conditions | Temperature          | Increasing temperature can promote bacterial growth.<br>Temperature can also affect bacterial community composition by providing competitive advantages to specific bacterial species in specified temperature ranges.                                                                                                                                                                                                                                                                                                                           |
|                      | Hydraulic conditions | Low flow can lead to low flow velocities and long retention time, providing favourable conditions for bacterial growth.<br>High flow can lead to increasing biofilm detachment and bacterial dispersal.                                                                                                                                                                                                                                                                                                                                          |
|                      | Pressure             | Operating modes of sewers include gravity modes and pressure modes.<br>Under gravity modes, DO level in sewers is high and dominant microorganisms are aerobic and facultative bacteria.<br>Under pressure modes, sewers are in anaerobic conditions and dominant microorganisms are anaerobic bacteria.                                                                                                                                                                                                                                         |
| Disinfectants        |                      | Dissolved nutrients, extra-cellular polymeric substances, organic and inorganic nutrients adsorbed on biofilm can react with disinfectants, resulting in consumption of disinfectants and promoting bacterial regrowth.                                                                                                                                                                                                                                                                                                                          |
| Pipeline materials   |                      | The composition of pipeline materials can affect biofilm development, including growth rates, bacterial densities and community compositions.<br>The corrosion of pipes can lead to release of particles and the formation of rough sinks on the pipe surfaces, on which organic and inorganic compounds and bacteria can be adsorbed, and which also protect bacteria from disinfectant residuals. The corrosion of iron pipes is easier than that of plastic pipes as higher bacterial abundance is found on iron pipes than on plastic pipes. |

## 5.2 Evaluation principles of water quality stability

The evaluation of water quality stability should consider the utilization of reclaimed water. Accordingly, evaluation parameters for water quality stability of reclaimed water should be selected based on equipment materials. Evaluation processes should follow the principles of accuracy, comprehensiveness and independence (listed in [Table 4](#)).

**Table 4 — Evaluation principles of water quality stability of reclaimed water**

| Principle         | Notes                                                                                                                                                                                                                                                           |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Accuracy          | Accurate and objective parameters should be recommended according to utilization, equipment materials and characteristics of reclaimed water.                                                                                                                   |
| Comprehensiveness | An appropriate number of evaluation parameters should be selected. The evaluation with multiple parameters is beneficial for accuracy of results. Excessive selection of parameters should be avoided due to the complexity and cost of the evaluation process. |
| Independence      | Independent parameters should be selected. If several parameters describe similar characteristics, one of them should be recommended.                                                                                                                           |

## 6 Evaluation system of water quality stability

The evaluation of water quality stability can be performed according to the framework depicted in [Figure 1](#). The following points show considerations for establishing a framework for water quality stability evaluation of reclaimed water.

- a) Reclaimed water use is a complex process. The evaluation of water quality stability should be based on the specific reuse conditions. Reuse conditions can vary based on applications, equipment and component materials and operating conditions. For example, when characteristics of reclaimed water change, different ionic components can react and form scales. The changes of thermodynamic conditions can lead to reclaimed water instability (e.g. temperature decrease can reduce the solubility of ionic components, thus leading to scaling; increasing temperature can promote bacterial growth). Besides, the extent of fouling is affected by, for example, hydraulic conditions and roughness of the contact surfaces. Water quality stability parameters for reclaimed water are respectively proposed according to chemical stability and biological stability. It is also necessary to supplement or omit some parameters according to the actual situation of different regions. Every parameter has its own characteristics, scopes and limits, and will be discussed in detail in [Clause 7](#). [Annex B](#) describes chemical stability evaluation parameters in urban water supply systems of some countries. [Annex C](#) and [D](#) describe evaluation parameters in water quality standards for boiler water and industrial water, respectively.
- b) The tendency of water quality stability for reclaimed water can be evaluated by comparing the determined or calculated values of selected parameters with critical values. The critical values determination usually needs to consider many factors, including social and economic levels and comprehensive utilization benefits of water reuse. It is recommended that generally accepted values are selected as critical values. Moreover, critical values need to be updated with the development of technology.
- c) Stability evaluation results for reclaimed water include corrosion, scale formation (including scaling and fouling) and relatively stable. They can be divided into five grades: severe corrosion, slight corrosion, relatively stable, slight scaling or fouling and severe scaling or fouling. Evaluation results should be accurate and comprehensive. The contingency and uncertainty in the evaluation process should be minimized or avoided if possible. Final stability evaluation conclusions for reclaimed water should be drawn based on evaluation results. Suggestions and improvement measures should be proposed.

The framework includes five steps ([Figure 1](#)). Specifically, the first step is to determine equipment and pipe materials and to collect given parameters of water quality characteristics for reclaimed water and operating conditions of a specific application. The second step is to select corresponding parameters based on the available information. The third step is to measure or calculate parameters for stability evaluation of reclaimed water. The fourth step is to compare calculated values with critical values. The last step is to analyse evaluation results and draw a conclusion.

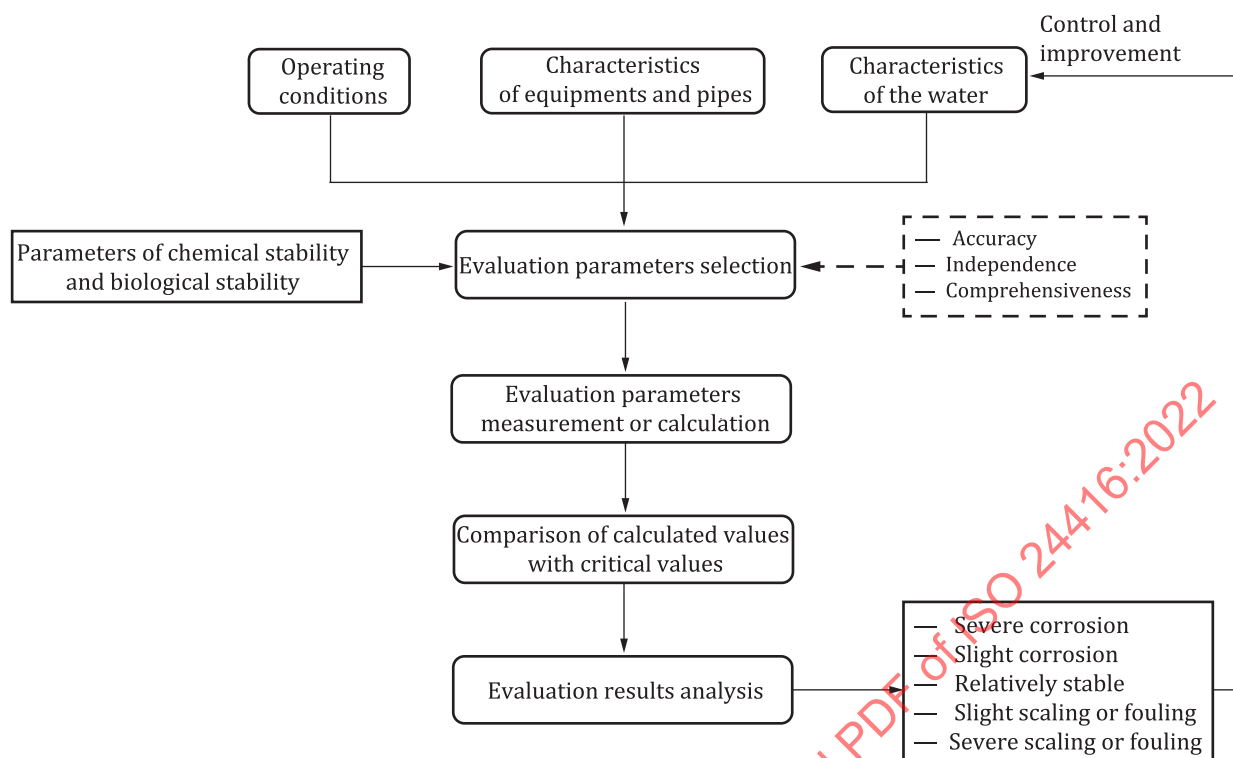


Figure 1 — Framework of water quality stability evaluation

## 7 Evaluation parameters of water quality stability

### 7.1 General

There are two kinds of stability parameters: single parameters and composite parameters. Single parameters such as pH, hardness and alkalinity are common parameters in water quality standards. The data of single parameters are easy to obtain. The data of composite parameters are usually calculated from single parameters. Calculation formulas of most composite parameters also consider multiple influencing factors, which is beneficial for comprehensively evaluating water quality stability. Those parameters with independent and complementary information should be selected to characterize the water quality stability.

### 7.2 Single parameters

A set of single parameters for stability evaluation of reclaimed water are proposed in [Table 5](#). The selection of evaluation parameters depends on water characteristics, characteristics of equipment and pipelines and operating conditions.

Table 5 — Single parameters for stability evaluation of reclaimed water

| Single parameters                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Units                              | Determination method   | Notes of significance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| pH                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | –                                  | ISO 3696               | The changes of pH can break many dynamic equilibrium reactions and affect ion concentration related to water quality stability.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Total hardness                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | mg/l calculated as $\text{CaCO}_3$ | ISO 6059               | High hardness can easily lead to scale formation; low hardness can easily lead to corrosion.<br><br>The World Health Organization (WHO) recommends an appropriate range of hardness in its <i>Guidelines for drinking-water quality</i> . If hardness is less than 100 mg $\text{CaCO}_3$ /l or exceeds 200 mg $\text{CaCO}_3$ /l, corrosion or scaling will respectively occur in the pipelines of drinking water. <sup>[2]</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Total alkalinity                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | mg/l calculated as $\text{CaCO}_3$ | ISO 9963-1             | Taking iron pipeline as an example, increasing alkalinity can promote the formation of ferrous carbonate ( $\text{FeCO}_3$ ), which is an intermediate corrosion product. Ferrous intermediate can then be oxidized to stable trivalent iron oxide (e.g. $\text{Fe}_3\text{O}_4$ , $\text{FeOOH}$ ). These products deposit on the pipelines and form passivation films, which can prevent further corrosion.<br><br>Changes of alkalinity can lead to changes of pH, which can affect the growth of certain types of bacteria.                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| DO                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | mg/l                               | ISO 5814 and ISO 17289 | When DO acts on the surface of the inner wall of metal pipelines, corrosion can be accelerated.<br><br>When DO acts on the surface of formed corrosion products, it can accelerate the formation of passivation films, which can delay or prevent further corrosion.<br><br>High DO levels can provide suitable conditions for aerobic bacteria growth, so that sulfates are not degraded by anaerobic sulfate-reducing bacteria generating corrosion and odours.<br><br>Low DO levels can provide suitable conditions for facultative bacteria growth, such as nitrate-reducing bacteria.<br><br>The absence of DO can provide suitable conditions for anaerobic bacteria growth, such as sulfate-reducing bacteria and iron-reducing bacteria.<br><br>DO levels can affect the structure of biofilms. Under aerobic conditions, biofilms can show a hollow and seeding dispersal structure. Under anaerobic conditions, biofilm can show a round and densely-packed structure. <sup>[11]</sup> |
| <p>NOTE 1 <a href="#">Annex E</a> lists some limits of pH, DO and TSS for different purposes of reclaimed water.</p> <p>NOTE 2 <a href="#">Annex F</a> lists some modified measurement methods based on the original AOC method.</p> <p>NOTE 3 <a href="#">Annex G</a> describes the biological stability guideline values for AOC.</p> <p>NOTE 4 <a href="#">Annex H</a> compares measurement methods for evaluation parameters of biological stability.</p> <p>NOTE 5 In ISO 20468-1, the monitoring parameters for non-potable water reuse projects can include biochemical oxygen demand (BOD), turbidity or TSS, <i>E. coli</i> and chlorine residual.</p> <p><b>Key</b></p> <p>CFU colony-forming unit</p> <p>NTU nephelometric turbidity unit</p> |                                    |                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

Table 5 (continued)

| Single parameters                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Units                             | Determination method                                                                                                                             | Notes of significance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TDS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | mg/l                              | ISO 7888                                                                                                                                         | <p>Among TDS, chloride has the highest influence on the corrosion of the carbon steel, followed by sulfate, nitrate and ammonium.<sup>[12]</sup></p> <p>High concentration of sulfate and chloride ions will increase conductivity of water, accelerate the migration rate of ions and electrons and promote corrosion; release of irons (sulfate and chloride ions) can promote the release of aluminium and manganese ions, but have little effect on the release of copper, chromium, zinc, nickel and arsenic ions.<sup>[14]</sup></p> <p>Nitrate can greatly accelerate the general corrosion of iron in acidic solutions but has only a slight influence on the general corrosion in neutral solutions.<sup>[3]</sup> Nitrate can be easily degraded by bacteria so that sulfate is not degraded in the sewer, generating corrosion and odours.</p> |
| TSS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | mg/l                              | ISO 11923                                                                                                                                        | <p>TSS are easily disturbed by water flow and can aggravate erosion of water flow on the inner wall of pipelines. Then, the corrosion surface layer can be scoured off in an accelerated manner, leading to aggravation of corrosion.</p> <p>TSS can also promote scale formation. Suspended solids are nuclei of salt crystals. Excessive suspended solids promote the formation of scales.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Turbidity                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | NTU                               | ISO 7027-1                                                                                                                                       | <p>The particle size of TSS is over 1 µm, while that of turbidity is between 1 nm and 1 µm, which is commonly called colloidal substances.<sup>[17]</sup> Because colloidal substances play an essential role in scaling, it is more accurate to select turbidity instead of TSS to describe water quality stability.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| AOC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | µg/l calculated as acetate carbon | Specific method is described in Reference [18]                                                                                                   | <p>AOC serve as carbon source and energy source for heterotrophic bacteria and can be converted to biomass by heterotrophic bacteria. It is generally recognized that the AOC level to keep biological stability is below 100 µg/l.<sup>[19,20]</sup></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| BGP                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | CFU/ml                            | <p>The maximum bacterial count after inoculation of indigenous bacteria and incubation</p> <p>Specific method is described in Reference [21]</p> | <p>The maximum bacterial count that can be achieved owing to diverse compounds available in water and complex interactions among indigenous bacterial population.</p> <p>Suitable application field: direct evaluation of what really happens in the water sample.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <p>NOTE 1 <a href="#">Annex E</a> lists some limits of pH, DO and TSS for different purposes of reclaimed water.</p> <p>NOTE 2 <a href="#">Annex F</a> lists some modified measurement methods based on the original AOC method.</p> <p>NOTE 3 <a href="#">Annex G</a> describes the biological stability guideline values for AOC.</p> <p>NOTE 4 <a href="#">Annex H</a> compares measurement methods for evaluation parameters of biological stability.</p> <p>NOTE 5 In ISO 20468-1, the monitoring parameters for non-potable water reuse projects can include biochemical oxygen demand (BOD), turbidity or TSS, <i>E. coli</i> and chlorine residual.</p> <p><b>Key</b></p> <p>CFU colony-forming unit</p> <p>NTU nephelometric turbidity unit</p> |                                   |                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

Table 5 (continued)

| Single parameters                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Units                         | Determination method                                                                                                                                                                                                                              | Notes of significance                                                                                                                                                                                                                                      |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| BFR                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | pg ATP/<br>cm <sup>2</sup> ·d | The flux of substrate through column or monitor<br>Specific method is described in Reference [22]                                                                                                                                                 | The rate and extent of biofilm formation as a function of time.<br>Suitable application field: determination of the ability of water to promote biomass accumulation.                                                                                      |
| BDOC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | mg/l                          | The difference between initial DOC and final DOC during incubation<br>Specific method is described in Reference [23]                                                                                                                              | The consumption of DOC to catabolize organic carbon to carbon dioxide and/or new biomass.<br>Suitable application field: evaluation of the reduction in chlorine demand or DBP formation potential through a biological process.                           |
| MAP                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | µg PO <sub>4</sub> -P/l       | The linear relationship between MAP value and the concentration of phosphorus<br>Specific method is described in Reference [24]                                                                                                                   | The bacterial maximum growth from inoculation until steady-state with phosphorus as the standard substrate.<br>Suitable application field: regions where microbial growth in water is restricted by phosphorus content rather than organic carbon content. |
| ATP                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | ng ATP/<br>cell               | The chemical and/or enzymatic extraction of ATP from bacterial cells, followed by the measurement of light emission derived when the dissolved ATP reacts with the luciferin/luciferase reagent<br>Specific method is described in Reference [25] | ATP is present in all living cells and it helps to estimate the total live biomass in a sample.<br>Suitable application field: ATP can be complementary to conventional parameters to account for bacterial dynamics in storage and distribution.          |
| <p>NOTE 1 <a href="#">Annex E</a> lists some limits of pH, DO and TSS for different purposes of reclaimed water.</p> <p>NOTE 2 <a href="#">Annex F</a> lists some modified measurement methods based on the original AOC method.</p> <p>NOTE 3 <a href="#">Annex G</a> describes the biological stability guideline values for AOC.</p> <p>NOTE 4 <a href="#">Annex H</a> compares measurement methods for evaluation parameters of biological stability.</p> <p>NOTE 5 In ISO 20468-1, the monitoring parameters for non-potable water reuse projects can include biochemical oxygen demand (BOD), turbidity or TSS, <i>E. coli</i> and chlorine residual.</p> <p><b>Key</b></p> <p>CFU colony-forming unit</p> <p>NTU nephelometric turbidity unit</p> |                               |                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                            |

### 7.3 Composite parameters

#### 7.3.1 General

Composite parameters are mainly divided into two kinds: the first based on calcium carbonate dissolution equilibrium and the second based on multi-parameter analysis. [Annex I](#) illustrates water quality stability evaluation conclusions for different composite parameters.

### 7.3.2 Langelier saturation index (LSI)

LSI is proposed on the basis of the solubility equilibrium of calcium carbonate. LSI is suitable to qualitatively evaluate the tendency of corrosion or scaling. LSI can be used to evaluate water chemical stability of metal pipelines without additives and internal corrosion protection, such as steel pipelines, cast iron pipelines and galvanized steel pipelines. But LSI also has its limits. The first is that two identical LSI values cannot be compared for chemical stability. The second is that when LSI value is near zero, it is easy to draw a contrary conclusion. See [Formula \(1\)](#).

$$I_{\text{LSI}} = \text{pH} - \text{pH}_s \quad (1)$$

where

$I_{\text{LSI}}$  is Langelier saturation index;

pH is the actual pH of water;

$\text{pH}_s$  is the pH at which calcium carbonate is at equilibrium.

[SOURCE: ISO 23446:2021, Annex B]

$\text{pH}_s$  can be calculated by many methods, including the calculation method, the table method and the image method. Besides being related to bicarbonate alkalinity, calcium ions concentration and water temperature in water,  $\text{pH}_s$  is also influenced by many factors such as salt content, calcium association ions and other components that can form alkalinity. Generally, from the perspective of simplified calculation, it is recommended that  $\text{pH}_s$  is calculated using [Formulae \(2\) to \(6\)](#):<sup>[28]</sup>

$$\text{pH}_s = (9,3 + A + B) - (C + D) \quad (2)$$

$$A = \frac{[\text{Log}_{10}(I_{\text{TDS}}) - 1]}{10} \quad (3)$$

$$B = -13,12 \times \text{Log}_{10} (^{\circ}\text{C} + 273) + 34,55 \quad (4)$$

$$C = \text{Log}_{10} (\text{Ca}^{2+} \text{ as CaCO}_3) - 0,4 \quad (5)$$

$$D = \text{Log}_{10} (\text{alkalinity as CaCO}_3) \quad (6)$$

where

$A$  is the dissolved solids coefficient of water quality;

$B$  is the temperature coefficient;

$C$  is the hardness coefficient;

$D$  is total alkalinity coefficient.

### 7.3.3 Ryznar stability index (RSI)

RSI is a parameter substantially modified from LSI. RSI is suitable for intercooled open-type recirculating cooling water system and is more accurate at pH 6,5 to pH 8. The US Environmental Protection Agency (USEPA) has recommended the use of LSI and RSI by utilities to monitor the corrosion potential of water.<sup>[29]</sup>

$$I_{\text{RSI}} = 2\text{pH}_s - \text{pH} = \text{pH}_s - I_{\text{LSI}} \quad (7)$$

where

- $I_{RSI}$  is Ryznar stability index;
- pH is the actual pH of water;
- $pH_S$  is the pH at which calcium carbonate is at equilibrium;
- $I_{LSI}$  is Langelier saturation index.

[SOURCE: ISO 22449-1: 2020, 3.1.10]

### 7.3.4 Calcium carbonate precipitation potential (CCPP)

CCPP can quantitatively reflect the precipitation or dissolution amount of calcium carbonate. When corrosive ions such as chloride ions are introduced into water, chemical stability cannot be accurately evaluated by CCPP alone. The CCPP can be calculated by alkalinity, see [Formula \(8\)](#).<sup>[28]</sup>

$$I_{CCPP} = 50\,000(I_{alki} - I_{alkeq}) \quad (8)$$

where

- $I_{CCPP}$  is calcium carbonate precipitation potential index;
- $I_{alki}$  is original alkalinity of water (mg/l calculated as  $CaCO_3$ );
- $I_{alkeq}$  is the alkalinity after calcium carbonate is balancing (mg/l calculated as  $CaCO_3$ ).

A higher CCPP value means more calcium carbonate precipitating on the inner wall of pipelines. Deposited films can prevent the dissolution and release of corrosion products from pipelines.

### 7.3.5 Aggressive index (AI)

AI is suitable for evaluating chemical stability of water quality in the cement pipelines. AI considers the effects of all ions in raw water on alkalinity, hardness and pH, see [Formula \(9\)](#).<sup>[28]</sup>

$$I_{AI} = pH + \text{Log}(I_{alk} \cdot I_{hardness}) \quad (9)$$

where

- $I_{AI}$  is the aggressive index;
- pH is the actual pH of water;
- $I_{alk}$  is the water alkalinity (mg/l calculated as  $CaCO_3$ );
- $I_{hardness}$  is the water hardness (mg/l calculated as  $CaCO_3$ ).

### 7.3.6 Larson corrosion index (LR)

LR is suitable to evaluate water chemical stability of iron pipelines, see [Formula \(10\)](#).<sup>[28]</sup>

$$I_{LR} = \frac{[Cl^-] + [SO_4^{2-}]}{[HCO_3^-]} \quad (10)$$

where

- $I_{LR}$  is Larson corrosion index;
- $[Cl^-]$  is the concentration of chloride (mol/l);
- $[SO_4^{2-}]$  is the concentration of sulfate (mol/l);
- $[HCO_3^-]$  is the concentration of bicarbonate (mg/l).

When water quality parameters such as pH, alkalinity and hardness have their own obvious change trends, water chemical stability cannot be evaluated by LR alone.<sup>[31]</sup> Considering the effects of various factors, such as water temperature, hydraulic residence time and DO, improved LR (ILR) was proposed on the basis of LR, see [Formula \(11\)](#).<sup>[28]</sup>

$$\text{Log}(I_{ILR}) = -1,922 + 0,3\text{Log}(I_{LR}) + 9,968\text{Log}\left(\frac{I_{\text{hardness}}}{100}\right) - 0,277\text{Log}\left(\frac{I_{DO}}{8}\right) - 2,417\text{Log}\left(\frac{T}{25}\right) - 0,088\text{Log}\left(\frac{I_{HRT}}{6}\right) \quad (11)$$

where

- $I_{ILR}$  is the improved LR index;
- $I_{LR}$  is the Larson corrosion index;
- $I_{\text{hardness}}$  is the hardness of water (mg/l calculated as  $CaCO_3$ );
- $I_{DO}$  is the concentration of dissolved oxygen (mg/l);
- $T$  is the temperature of water ( $^{\circ}C$ );
- $I_{HRT}$  is the hydraulic retention time (h).

### 7.3.7 Riddick corrosion index (RI)

RI is suitable for evaluating water chemical stability with low hardness. Besides introducing conventional parameters related to corrosion, this parameter also considers the effect of hardness, alkalinity, nitrate, chloride, DO and silicon dioxide, see [Formula \(12\)](#).<sup>[28]</sup>

$$I_{RI} = \frac{75}{I_{alk}} \left[ I_{CO_2} + \frac{1}{2} (I_{\text{hardness}} - I_{alk}) + [Cl^-] + 2[NO_3^-] \right] \left( \frac{10}{I_{SiO_2}} \right) \left( \frac{I_{DO} + 2}{I_{DO_s}} \right) \quad (12)$$

where

- $I_{RI}$  is Riddick corrosion index;
- $I_{DO}$  is the concentration of dissolved oxygen (mg/l);
- $I_{DO_s}$  is the concentration of dissolved oxygen at saturation (mg/l).

When there is no corresponding data of silica, DO or both, product term of silica and DO can be deleted.

[Table 6](#) lists the determination methods of necessary parameters in the formula.

**Table 6 — The determination methods of necessary parameters**

| Parameter | Determination methods    |
|-----------|--------------------------|
| $Ca^{2+}$ | ISO 6058                 |
| $Cl^-$    | ISO 9297 and ISO 10304-1 |

Table 6 (continued)

| Parameter                     | Determination methods      |
|-------------------------------|----------------------------|
| SO <sub>4</sub> <sup>2-</sup> | ISO 10304-1                |
| HCO <sub>3</sub> <sup>-</sup> | ISO 9963                   |
| NO <sub>3</sub> <sup>-</sup>  | ISO 7890-3 and ISO 10304-1 |
| CO <sub>2</sub>               | ASTM D513-02               |
| SiO <sub>2</sub>              | GB/T 12149                 |
| DO                            | ISO 5814 and ISO 17289     |

#### 7.4 Selection principles of evaluation parameters

The following points indicate considerations for selecting evaluation parameters for water quality stability of reclaimed water.

- Water quality characteristics: The selection of evaluation parameters should consider water quality characteristics of reclaimed water. More specifically, among six composite parameters, only AI can be used to evaluate the chemical stability of different water quality characteristics. LSI is suitable for qualitative evaluation of chemical stability of water not containing additives. RSI is more accurate at pH 6,5 to pH 8. If corrosive ions such as chloride ions are introduced into water, chemical stability cannot be accurately evaluated by CCPP alone. When water quality parameters such as pH, alkalinity and hardness have their own obvious change trends, chemical stability cannot be evaluated by LR alone. RI is suitable for evaluating water chemical stability with low hardness. Among the six parameters presented for biological stability, AOC can evaluate microbial regrowth in various water qualities.
- Utilization and equipment materials: Considering reclaimed water has various utilizations, the selection of evaluation parameters should consider equipment materials related to reclaimed water. For example, LSI and RSI are suitable for metal pipelines. AI is suitable for cement pipelines. LR is suitable for iron pipelines. CCPP and RI are suitable for various materials (listed in [Table 7](#)). Six parameters for biological stability are suitable for various equipment materials.
- Evaluation parameter characteristics: Among the six composite parameters presented for chemical stability, LSI, RSI and CCPP are suitable for evaluating the tendency of corrosion or scaling or for being stable, and AI, LR and RI are suitable for evaluating the tendency of corrosion or being stable. Among the six single parameters presented for biological stability, AOC and BDOC are suitable for situations when microbial growth in water is restricted by organic carbon content, and MAP is suitable for situations that microbial growth in water is restricted by phosphorus content. BGP and BFR can evaluate the ability of water to promote biomass accumulation, including the effects of various nutrients on bacterial growth. ATP is complementary to the other five conventional parameters for estimating the total living biomass in samples.
- Combination of various parameters: In order to comprehensively evaluate stability of reclaimed water, it is recommended that various kinds of parameters, including single and composite parameters, are selected. Among the composite parameters, the parameters of both calcium carbonate dissolution equilibrium and multi-parameter analysis are suggested. More specifically, LSI, RSI and CCPP are parameters based on the calcium carbonate dissolution equilibrium, which can be used to evaluate the scaling of calcium carbonate. AI, LR, RI are parameters based on multi-parameter analysis, which can be used to evaluate the scaling of other minerals.

**Table 7 — Optional stability evaluation parameters for different pipelines**

| Parameter | Pipeline material          |                                                    |         |                                 |                   |
|-----------|----------------------------|----------------------------------------------------|---------|---------------------------------|-------------------|
|           | Steel and galvanized steel | Concrete and cement, and cement-mortar-lined metal | Plastic | Cast iron and ductile cast iron | Non-ferrous metal |
| LSI       | •                          |                                                    |         | •                               | •                 |
| RSI       | •                          |                                                    |         | •                               | •                 |
| CCPP      | •                          | •                                                  | •       | •                               | •                 |
| AI        |                            | •                                                  |         |                                 |                   |
| LR        |                            |                                                    |         | •                               |                   |
| ILR       |                            |                                                    |         | •                               |                   |
| RI        | •                          | •                                                  | •       | •                               | •                 |

NOTE The dot “•” indicates that attention should be paid to this category.

## 7.5 Case study of evaluation parameters selection

The selection of evaluation parameters is the most difficult step during the entire evaluation process, which affects the accuracy of the evaluation results. Combined with the selection principles of evaluation parameters, one case is illustrated to clearly show how to select indicators for water stability evaluation. The corresponding information of reclaimed water is listed in [Table 8](#).

**Table 8 — Information of reclaimed water for water stability evaluation**

| Pipe-line material | pH   | $T$<br>(°C) | $\text{PO}_4^{3-}\text{-P}$<br>(mg/l) | $\text{Ca}^{2+}$<br>(mg/l)<br>as $\text{CaCO}_3$ | TN<br>(mg/l) | $\text{NH}_4^+\text{-N}$<br>(mg/l) | $\text{NO}_3^-\text{-N}$<br>(mg/l) | $\text{Cl}^-$<br>(mg/l) | $\text{SO}_4^{2-}$<br>(mg/l) | TDS<br>(mg/l) | Total hardness<br>(mg/l) | Total alkalinity<br>(mg/l) |
|--------------------|------|-------------|---------------------------------------|--------------------------------------------------|--------------|------------------------------------|------------------------------------|-------------------------|------------------------------|---------------|--------------------------|----------------------------|
| Steel              | 6,98 | 25          | 0,27                                  | 240                                              | 9,58         | 0,18                               | 8,36                               | 62,9                    | 56,8                         | 142,9         | 181                      | 97,8                       |

In terms of chemical stability, optional parameters for steel pipelines include LSI, RSI, CCPP and RI. Among them, LSI, RSI and CCPP are parameters based on the calcium carbonate dissolution equilibrium, and RI is a parameter based on multi-parameter analysis. It is recommended that one parameter is selected for each class of two classes (parameters of calcium carbonate dissolution equilibrium and parameters of multi-parameter analysis). Considering the characteristics of reclaimed water, RI is firstly excluded because water hardness is relatively high. CCPP cannot accurately describe chemical stability alone when corrosive ions (chloride and sulfate ions) exist in the water. Between LSI and RSI, RSI is more accurate at pH 6,5 to pH 8. Therefore, RSI is selected as the composite parameter for chemical stability evaluation. The formula of RSI considers the effect of pH value, so pH is not selected as a single parameter again. The remaining single parameters, including hardness, alkalinity, DO, TDS and turbidity, are selected. Among them, TDS is especially important, for it reflects the effects of chloride and sulfate ions. The evaluation parameters for chemical stability are determined as hardness, alkalinity, DO, TDS, turbidity and RSI. According to the formula of RSI, the calculated value of RSI is 8,09 > critical value 6, therefore the evaluation conclusion for chemical stability evaluated by RSI is corrosive.

In terms of biological stability, the ratio of C:P under this condition needs to be calculated and compared with the ratio favourable for bacterial growth (e.g. the ratio of 100:1), and then it can be determined whether phosphorous acts as a limiting factor for bacterial growth. If the answer is yes, MAP is selected as the evaluation parameter for biological stability. If the answer is no, AOC is selected. Besides, it is obvious that the contents of nitrogen ( $\text{NH}_4^+\text{-N}$  and  $\text{NO}_3^-\text{-N}$ ) are high, which can promote bacterial growth and activity (ammonia-oxidizing bacteria and nitrate-reducing bacteria) and further affect biological stability, so BGP is selected to evaluate what really happens in the water sample. The evaluation parameters for biological stability are determined as AOC (or MAP) and BGP.

## 8 Evaluation parameters of water quality stability for pipeline networks

Pipeline networks are important parts for transportation and distribution of reclaimed water. Water quality stability for reclaimed water is affected by many factors, such as hydraulic conditions and pipeline materials. The influence of pipeline materials is mainly embodied in the surface condition, such as roughness coefficient and chemical composition of pipelines. There are many kinds of water supply pipeline networks. Common pipeline materials include metal, non-metal and composite types. Metal pipelines include cast-iron pipelines, steel pipelines and copper pipelines. Non-metal pipelines include plastic pipelines and concrete pipelines. It is recommended that stability evaluation parameters are selected based on pipeline materials. [Table 9](#) lists optional recommended stability evaluation parameters for pipeline networks.

**Table 9 — Evaluation parameters of water quality stability for pipeline networks**

| Parameter           |            | Pipeline network           |                                                              |         |                                 |                   |
|---------------------|------------|----------------------------|--------------------------------------------------------------|---------|---------------------------------|-------------------|
|                     |            | Steel and galvanized steel | Concrete and cement pipelines, and cement-mortar-lined metal | Plastic | Cast iron and ductile cast iron | Non-ferrous metal |
| Single parameter    | pH         | •                          | •                                                            | •       | •                               | •                 |
|                     | Hardness   | •                          | •                                                            |         | •                               | •                 |
|                     | Alkalinity | •                          | •                                                            |         | •                               | •                 |
|                     | DO         | •                          | •                                                            |         | •                               | •                 |
|                     | TDS        | •                          | •                                                            |         | •                               | •                 |
|                     | Turbidity  | •                          | •                                                            | •       | •                               | •                 |
|                     | AOC        | •                          | •                                                            | •       | •                               | •                 |
|                     | MAP        | •                          | •                                                            | •       | •                               | •                 |
|                     | BGP        | •                          | •                                                            | •       | •                               | •                 |
|                     |            |                            |                                                              |         |                                 |                   |
| Composite parameter | LSI        |                            |                                                              |         | •                               |                   |
|                     | RSI        | •                          |                                                              |         |                                 |                   |
|                     | CCPP       |                            |                                                              | •       |                                 | •                 |
|                     | AI         |                            | •                                                            |         |                                 |                   |
|                     | ILR        |                            |                                                              |         | •                               |                   |
|                     | RI         | •                          |                                                              |         |                                 | •                 |

NOTE The dot “•” indicates that attention should be paid to this category.

## 9 Evaluation parameters of water quality stability for equipment

Reclaimed water is widely used in many fields with various modes, and the types of related equipment are quite different. Cooling water is the highest utilization for industrial applications of reclaimed water. In addition, reclaimed water is usually used as toilet flushing water and landscape water. [Annex J](#) and [Annex K](#), respectively, provide guideline values for reclaimed water used in toilet and urinal flushing and recreational purposes. [Table 10](#) lists optional recommended stability evaluation parameters for common equipment.

Table 10 — Evaluation parameters of water quality stability for equipment

| Parameter           |            | Equipment                 |                  |                                     |                      |
|---------------------|------------|---------------------------|------------------|-------------------------------------|----------------------|
|                     |            | Boiler and heat exchanger | Air conditioning | Toilet-flushing device <sup>a</sup> | Irrigation equipment |
| Single parameter    | pH         | •                         | •                | •                                   | •                    |
|                     | Hardness   | •                         | •                |                                     | •                    |
|                     | Alkalinity | •                         | •                |                                     | •                    |
|                     | DO         | •                         | •                |                                     | •                    |
|                     | TDS        | •                         | •                |                                     | •                    |
|                     | Turbidity  | •                         | •                | •                                   | •                    |
|                     | AOC        | •                         | •                | •                                   | •                    |
|                     | MAP        | •                         | •                | •                                   | •                    |
|                     | BGP        | •                         | •                | •                                   | •                    |
|                     | LSI        |                           |                  |                                     | •                    |
| Composite parameter | RSI        | •                         |                  |                                     |                      |
|                     | CCPP       |                           | •                | •                                   |                      |
|                     | ILR        | •                         |                  |                                     |                      |
|                     | RI         |                           | •                |                                     | •                    |

NOTE The dot “•” indicates that attention should be paid to this category.

<sup>a</sup> Some countries and regions regulate that reclaimed water used for toilet and urinal flushing should be disinfected.

The selection of evaluation parameters is affected by a variety of factors, and the selection of evaluation indicators still needs to be combined with specific situations of different regions. Appropriate modifications are needed under certain circumstances.

## Annex A (informative)

### Information on corrosion types

[Table A.1](#) describes common corrosion types of metals and alloys.

**Table A.1 — Corrosion types of metals and alloys**

| Corrosion type                         | Notes                                                                                                                                                    |
|----------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| Electrochemical corrosion              | Corrosion involving at least one anodic reaction and one cathodic reaction                                                                               |
| Chemical corrosion                     | Corrosion not involving electrochemical reaction                                                                                                         |
| General corrosion                      | Corrosion proceeding over whole surface of the metal exposed to the corrosive environment                                                                |
| Localized corrosion                    | Corrosion preferentially concentrated on discrete sites of the metal surface exposed to corrosive environment                                            |
| Uniform corrosion                      | General corrosion proceeding at almost the same rate over whole surface                                                                                  |
| Pitting corrosion                      | Localized corrosion resulting in pits, i.e. cavities extending from the surface into the metal                                                           |
| Layer corrosion                        | Corrosion of internal layers of wrought metal, occasionally resulting in exfoliation, i.e. detachment of unattacked layers                               |
| Deposit corrosion                      | Localized corrosion associated with, and taking place under or immediately around, a deposit of corrosion products or other substance                    |
| Microbiologically influenced corrosion | Accelerated deterioration of metals owing to the presence of biofilms on their surfaces                                                                  |
| High-temperature corrosion             | Corrosion by gases or deposits or both gases and deposits occurring at elevated temperatures under conditions where aqueous electrolytes no longer exist |

## Annex B

### (informative)

## Chemical stability guidelines for water quality in urban water supply systems of some countries

[Table B.1](#) describes chemical stability guidelines for water quality in urban water supply systems of some countries.

**Table B.1 — Chemical stability parameters in urban water supply systems**

| Parameter                                                                                                    | Norway     | Denmark   | UK         | USA        | Canada     | Germany    |
|--------------------------------------------------------------------------------------------------------------|------------|-----------|------------|------------|------------|------------|
| pH                                                                                                           | 7,5 to 8,5 | 8         | 5,5 to 9,5 | 6,5 to 8,5 | 6,5 to 6,8 | 6,5 to 9,5 |
| Alkalinity (mg/l)                                                                                            | 60 to 100  | > 160     | > 50       | –          | –          | –          |
| Hardness (mg/l)                                                                                              | 15 to 25   | 20 to 200 | –          | –          | –          | –          |
| Chloride (mg/l)                                                                                              | < 100      | < 50      | –          | < 250      | < 250      | < 250      |
| Sulfate (mg/l)                                                                                               | < 100      | < 50      | –          | < 250      | < 250      | < 240      |
| Iron (mg/l)                                                                                                  | < 0,1      | 0,05      | –          | < 0,3      | < 0,3      | ≤ 0,2      |
| Manganese (mg/l)                                                                                             | 0,05       | 0,02      | –          | 0,05       | 0,05       | ≤ 0,05     |
| Aluminium (mg/l)                                                                                             | 0,1        | 0,05      | –          | 0,1        | 0,1        | ≤ 0,2      |
| Langelier saturation index                                                                                   | –          | –         | –          | 0          | –          | 0          |
| $[(\text{SO}_4^{2-}) + (\text{Cl}^-)] / [\text{HCO}_3^-]$                                                    | –          | –         | –          | –          | –          | < 1        |
| NOTE The values for chemical stability parameters in urban water supply systems are based on Reference [38]. |            |           |            |            |            |            |

## Annex C

### (informative)

## Guidelines for water conditioning of boiler water in Japan

[Table C.1](#) describes guidelines for water conditioning of boiler water in Japan.

**Table C.1 — Guidelines for water conditioning of boiler water**

| Parameter                                                                                              | Cylindrical boiler |          | Multitubular special circulation boiler |          |              |              | Water tube boiler |          |
|--------------------------------------------------------------------------------------------------------|--------------------|----------|-----------------------------------------|----------|--------------|--------------|-------------------|----------|
| Normal operating pressure (MPa)                                                                        | ≤ 1                | > 1, ≤ 2 | ≤ 1                                     | > 1, ≤ 3 | ≤ 2          | > 2, ≤ 3     | ≤ 1               | > 1, ≤ 2 |
| pH                                                                                                     | 11,0 to 11,8       |          | 11,0 to 11,8                            |          | 10,5 to 11,5 | 10,0 to 11,0 | 11,0 to 11,8      |          |
| Acid consumption (pH 4,8, mg/l CaCO <sub>3</sub> )                                                     | 100 to 800         | 600 max. | 100 to 800                              | 600 max. | 250 max.     | 150 max.     | 100 to 800        | 600 max. |
| Acid consumption (pH 8,3, mg/l CaCO <sub>3</sub> )                                                     | 80 to 600          | 500 max. | 80 to 600                               | 500 max. | 200 max.     | 120 max.     | 80 to 600         | 500 max. |
| Conductivity (mS/m)                                                                                    | 400 to 600 max.    | 350 max. | 400 max.                                | 300 max. | 150 max.     | 100 max.     | 400 max.          | 300 max. |
| Chloride (mg/l)                                                                                        | 400 to 600 max.    | 350 max. | 400 max.                                | 300 max. | 150 max.     | 100 max.     | 400 max.          | 300 max. |
| Phosphate (mg/l)                                                                                       | 20 to 40           |          | 20 to 40                                |          | 10 to 30     | 5 to 15      | 20 to 40          |          |
| Sulfite (mg/l)                                                                                         | 10 min.            |          | 10 min.                                 | 10 to 20 | 10 to 20     | 5 to 10      | 10 min.           | 10 to 20 |
| NOTE The parameter values for water conditioning of boiler water in Japan are based on Reference [39]. |                    |          |                                         |          |              |              |                   |          |

## Annex D (informative)

### Reuse of urban recycling water — Water quality standard for industrial use in China

[Table D.1](#) details the water quality standard for industrial uses of urban recycling water in China.

**Table D.1 — Water quality standard for industrial uses of urban recycling water in China**

| Parameter                                       | Cooling water              |                                       | Washing water | Boiler make-up water | Process and product water |
|-------------------------------------------------|----------------------------|---------------------------------------|---------------|----------------------|---------------------------|
|                                                 | Once-through cooling water | Open-type recirculating cooling water |               |                      |                           |
| pH                                              | 6,5 to 9,0                 | 6,5 to 8,5                            | 6,5 to 9,0    | 6,5 to 8,5           | 6,5 to 8,5                |
| TSS ≤<br>(mg/l)                                 | 30                         | –                                     | 30            | –                    | –                         |
| Turbidity ≤<br>(NTU)                            | –                          | 5                                     | –             | 5                    | 5                         |
| Colour ≤<br>(Hazen)                             | 30                         | 30                                    | 30            | 30                   | 30                        |
| BOD <sub>5</sub> ≤<br>(mg/l)                    | 30                         | 10                                    | 30            | 10                   | 10                        |
| COD <sub>Cr</sub> ≤<br>(mg/l)                   | –                          | 60                                    | –             | 60                   | 60                        |
| Fe ≤<br>(mg/l)                                  | –                          | 0,3                                   | 0,3           | 0,3                  | 0,3                       |
| Mn ≤<br>(mg/l)                                  | –                          | 0,1                                   | 0,1           | 0,1                  | 0,1                       |
| Chloride ≤<br>(mg/l)                            | 250                        | 250                                   | 250           | 250                  | 250                       |
| Silica ≤<br>(mg/l)                              | 50                         | 50                                    | –             | 30                   | 30                        |
| Total hardness ≤<br>(mg/l CaCO <sub>3</sub> )   | 450                        | 450                                   | 450           | 450                  | 450                       |
| Total alkalinity ≤<br>(mg/l CaCO <sub>3</sub> ) | 350                        | 350                                   | 350           | 350                  | 350                       |
| Sulfate ≤<br>(mg/l)                             | 600                        | 250                                   | 250           | 250                  | 250                       |

NOTE The parameter values for industrial water are based on Reference [40].

#### Key

BOD<sub>5</sub> five-day biochemical oxygen demand

CFU colony-forming unit

NTU nephelometric turbidity unit

Table D.1 (continued)

| Parameter                                                                                                                                                                                                                             | Cooling water              |                                       | Washing water | Boiler make-up water | Process and product water |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|---------------------------------------|---------------|----------------------|---------------------------|
|                                                                                                                                                                                                                                       | Once-through cooling water | Open-type recirculating cooling water |               |                      |                           |
| $\text{NH}_3\text{-N} \leq$<br>(mg/l)                                                                                                                                                                                                 | –                          | 10                                    | –             | 10                   | 10                        |
| Total phosphorus $\leq$<br>(mg/l)                                                                                                                                                                                                     | –                          | 1                                     | –             | 1                    | 1                         |
| TDS $\leq$<br>(mg/l)                                                                                                                                                                                                                  | 1 000                      | 1 000                                 | 1 000         | 1 000                | 1 000                     |
| Petroleum $\leq$<br>(mg/l)                                                                                                                                                                                                            | –                          | 1                                     | –             | 1                    | 1                         |
| Anionic surfactant $\leq$<br>(mg/l)                                                                                                                                                                                                   | –                          | 0,5                                   | –             | 0,5                  | 0,5                       |
| Residual chlorine $\geq$<br>(mg/l)                                                                                                                                                                                                    | 0,05                       | 0,05                                  | 0,05          | 0,05                 | 0,05                      |
| Faecal coliforms $\leq$<br>(CFU/1 000 ml)                                                                                                                                                                                             | 2 000                      | 2 000                                 | 2 000         | 2 000                | 2 000                     |
| <p>NOTE The parameter values for industrial water are based on Reference [40].</p> <p><b>Key</b></p> <p>BOD<sub>5</sub> five-day biochemical oxygen demand</p> <p>CFU colony-forming unit</p> <p>NTU nephelometric turbidity unit</p> |                            |                                       |               |                      |                           |

## Annex E

### (informative)

## Water quality parameter limits of reclaimed water depending on specific use

[Table E.1](#) lists some water quality parameter limits of reclaimed water depending on specific use.

**Table E.1 — Water quality parameter limits of reclaimed water depending on specific use**

| Parameters | Private, urban and irrigation | Environmental and aquaculture | Indirect aquifer recharge | Industrial cooling |
|------------|-------------------------------|-------------------------------|---------------------------|--------------------|
| pH         | 6,0 to 9,5                    | 6,0 to 9,5                    | 7 to 9                    | 7,0 to 8,5         |
| DO (mg/l)  | > 0,5                         | > 3                           | > 8                       | > 3                |
| TSS (mg/l) | 10 to 20                      | 10 to 20                      | –                         | 10 to 20           |

## Annex F (informative)

### Modification methods based on the original AOC method

[Table F.1](#) lists some modified measurement methods based on the original AOC method.

**Table F.1 — Modified measurement methods based on the original AOC method**

| References | Modification                                                                                                            | Notes                                |
|------------|-------------------------------------------------------------------------------------------------------------------------|--------------------------------------|
| [41], [42] | Standardized AOC method based on stepwise inoculation with <i>Pseudomonas fluorescens</i> P-17 and <i>Spirillum NOX</i> | Original method                      |
| [43]       | Incorporation of four species in the inoculum                                                                           | Increased speed                      |
| [44]       | A single fast growing <i>Acinetobacter</i> used for the inoculum                                                        |                                      |
| [45]       | Increased inoculation density                                                                                           |                                      |
| [19]       | Increased incubation temperature                                                                                        |                                      |
| [46]       | Rapid macroscopic technique                                                                                             |                                      |
| [47]       | Rapid technique based on flow cytometry                                                                                 |                                      |
| [48]       | 40-ml vials batched instead of 1-l flask                                                                                | Reduction of contamination potential |
| [49]       | Natural microbial consortium used for inoculum                                                                          | Greater sensitivity                  |
| [50]       | Samples heated to 72 °C then cooled on ice instead of pasteurization                                                    | Greater biostability                 |
| [51]       | Use of membranes to sterilize the water instead of pasteurization                                                       |                                      |

## Annex G (informative)

### Biological stability guideline values for AOC

[Table G.1](#) describes the biological stability guideline values for AOC.

**Table G.1 — Biological stability guideline values for AOC**

| References | Parameters                | Units | Reported values |
|------------|---------------------------|-------|-----------------|
| [50]       | AOC<br>(without chlorine) | µg/l  | 2 to 311        |
| [51]       |                           |       | 4 to 130        |
| [52], [53] |                           |       | < 10            |
| [54]       | AOC<br>(with chlorine)    |       | 92 to 482       |
| [55]       |                           |       | 36 to 446       |
| [19], [20] |                           |       | 50 to 100       |
| [56]       |                           |       | < 200           |

## Annex H (informative)

### Comparison of measurement methods for evaluation parameters of biological stability

[Table H.1](#) compares the measurement methods for evaluation parameters of biological stability.

**Table H.1 — Comparison of measurement methods for evaluation parameters of biological stability**

| Method                                                          | AOC                   | BGP                   | BFR                          | BDOC                                         | MAP                     | ATP                 |
|-----------------------------------------------------------------|-----------------------|-----------------------|------------------------------|----------------------------------------------|-------------------------|---------------------|
| Inoculation                                                     | Pure bacteria         | Indigenous bacteria   | Indigenous bacteria          | Indigenous bacteria                          | Pure bacteria           | Indigenous bacteria |
| Incubation temperature                                          | 20 °C                 | 20 °C                 | > 10 °C                      | 22–25 °C                                     | 22 °C                   | 30 °C               |
| Incubation time                                                 | 3 d to 5 d            | 5 d to 7 d            | Weeks to months              | 28 d                                         | 3 d                     | 1 d to 5 d          |
| Results                                                         | Total microbial count | Total microbial count | Adenosine triphosphate (ATP) | Difference between initial DOC and final DOC | Amount of phosphorus    | ATP                 |
| Expression                                                      | Acetate carbon        | Cells per millilitre  | pg ATP/cm <sup>2</sup> ·d    | Organic carbon                               | µg PO <sub>4</sub> -P/L | ng ATP/cell         |
| NOTE The comparison is based on References [22], [57] and [58]. |                       |                       |                              |                                              |                         |                     |